APPENDIX C. ADAPTATION MEASURES

An adaptation measure is an action that minimizes risks from sea-level rise. Examples include changes in siting and design requirements, elevating the foundation of an individual structure, or moving a structure inland. Many adaptation measures benefit multiple coastal resources, and some adaptation measures fit into multiple categories, as shown the in tables below. Implied in each of these measures is the goal to protect and restore current and future coastal and marine resources and existing development, in accordance with the policies of the Coastal Act.

The Commission staff has compiled a list of potential adaptation measures for use in coastal development permitting and planning efforts and divided the measures into seven categories based on the requirements of the California Coastal Act. The adaptation measures in each category are listed in alphabetical order in the following tables.[45]

1. **Community Level Planning** – Table 16
2. **Site Development Standards and/or Mitigation –** Table 17
3. **Shoreline Protection and Management –** Table 18
4. **Natural Resources –** Table 19
5. **Water Quality and Water Supply Management –** Table 20
6. **Other Adaptation Measures –** Table 21

Description of Adaptation Measures

1. Community Level Planning Measures

Community level planning includes adaptation measures that are designed to guide development at a community, neighborhood, or hazard area scale. The measures generally apply to more than one parcel. Community level planning measures include:

- Concentration of development/Smart Growth
- Design standards
- Hazard zoning/ Overlay zones
- Land division requirements
- Transfer of Development Rights programs (TDR)
- Preserving open space
- Conservation easement programs
- Regional Sediment Management (RMS) programs

[45] The list of adaptation measures and descriptions were adapted and compiled various sources, including NOAA's "Adaptation to Climate Change: A Planning Guide for State Coastal Managers" (NOAA, 2010), Georgetown Climate Center's "Adaptation Tool Kit: Sea Level Rise and Coastal Land Use" (Grannis, 2011), EPA's Climate Ready Estuaries "Synthesis of Adaptation Options for Coastal Areas" (EPA, 2009), and Coastal Commission staff (personal communication, 2012-2013).

Table 16. Community Level Planning

Adaptation Measure	Description	Applicability to sea-level rise
Concentration of development/ Smart Growth	Require development to concentrate in areas that can accommodate it without significant adverse effects on coastal resources. This action should be consistent with Section 30250 and other policies of the Coastal Act.	Concentrate new development away from areas that are highly vulnerable to sea-level rise. This action is also applicable to CDPs for multiple lots.
Design standards	Establish and implement standards for building construction that minimize risks from flooding and erosion and increase resilience to extreme events.	LCPs should establish building standards to minimize hazards from sea-level rise. Standards may include higher base flood elevations, floating structures, and easily moveable structures, as well as strategies to reduce impacts from flood waters, such as green infrastructure and pervious surfaces.
Hazard zoning/ Overlay zones	Requires that new development is sited and designed to avoid highly hazardous or environmentally sensitive areas.	Update land use designations and zoning to identify areas that are vulnerable to sea-level rise impacts and to develop special regulations for those areas. Zoning regulations will need to be certified through an LCP Amendment.
Land division Requirements	Establish requirements for land divisions, lot creation, and lot line adjustments.	LCPs should limit subdivisions in hazard areas or require lots to meet specific standards in order to protect resources and prevent hazards. Also applicable to CDP.
Transfer of Development Rights programs (TDR)	Restrict development in one area ("sending area") and allow for the transfer of development rights to another area more appropriate for intense use ("receiving area").	LCPs can establish policies to implement a TDR program to restrict development in areas vulnerable to sea-level rise and allow for transfer of development rights to inland parcels with less vulnerability to hazards.
Preserving open space	Preserve land for its ecological or recreational value. Includes prohibiting development and any uses that conflict with ecological preservation goals.	LCPs can promote the preservation of open space, especially undeveloped areas vulnerable to sea-level rise impacts, through zoning restrictions or establishment of a defined urban/rural boundary.

Conservation easement program	Establish a formalized program to identify, acquire, and manage areas appropriate for some form of conservation protection. The program might develop standard agreements to be used for easements and chain of title, and identify the entities that could hold the easements.	LCPs can use a conservation easement program to limit or restrict development on portions of a lot parcel that would be most vulnerable to sea-level rise impacts. Parcel by parcel application would be accomplished through the CDP.
Regional Sediment Management (RSM) Program	Manage sediment to benefit a region, allow use of natural processes to solve engineering problems. To be most effective RSM will include the entire watershed, account for effects of human activities on sediment and protect and enhance coastal ecosystems.	LCPs can include support for development of an RSM program, and, once developed, supporting the management efforts identified by the RSM, and requiring that the plans be updated to include changes from sea-level rise. Natural boundaries for RSM may overlap with portions of several LCPs, so cooperation may be needed for best implementation. Individual actions would be accomplished through a CDP.

2. Site Development Standards and/or Mitigation

Site development standards are adaptation measures that are designed to reduce risks from sea-level rise at the individual parcel level. Mitigation measures are actions required as part of a coastal development permit to minimize hazards or adverse impacts to coastal resources. These include:

- Conditional permitting of shoreline protection structures
- Conservation easements
- Infrastructure-service protection
- Permit conditions
- Real estate disclosure
- Redevelopment restrictions
- Setbacks
- Siting and design

Table 17. Site Development Standards and/or Mitigation

Category	Description	Applicability to sea-level rise
Conditional permitting of shoreline protection structures	Add conditions to the shoreline protection permits, such as conditions that require the removal or modification of armoring in the future if need for protection or site conditions change.	Require shoreline protection to be removed, or considered for removal if the structure for which it was installed no longer exists or needs protection.
Conservation Easements	Provide a flexible mechanism by which a land trust or public entity can preserve land in its natural state while allowing land to remain in private ownership.	Where applicable, conservation easements can be required as a condition of a CDP. Also, LCPs can include policies to specify when such mitigation is appropriate or required.
Infrastructure-service protection	Establish measures that ensure continued function of critical infrastructure, or the basic facilities, services, networks, and systems needed for the functioning of a community.	LCPs can identify critical infrastructure vulnerable to hazards from sea-level rise, and can include criteria for managed relocation of at-risk facilities and direction to ensure continued function of critical infrastructure given sea-level rise and extreme storms. Can involve repair and maintenance, elevation or spot-protection of key components or fortification of structures where consistent with the Coastal Act.
Permit conditions	Conditionally approve a CDP to identify and require resource protective mitigation necessary to address impacts associated with locating development in an area subject to sea-level rise.	To mitigate impacts associated with locating new development in areas subject to sea-level rise, CDPs can include conditions that require: removal of structures if threatened, conservation easements, flood protection measures commensurate with rising sea level, and waiver of any rights to future shoreline protection.
Real estate disclosure	Require sellers of real estate to disclose certain property defects to prospective buyers prior to close. This action enables potential buyers to make informed decisions regarding the level of impacts they may experience.	Disclosures should include information about known current and potential vulnerabilities to sea-level rise.

Redevelopment restrictions	Limit the extent of redevelopment that can occur in hazardous areas without a Coastal Development Permit.	LCPs should clarify the definition of redevelopment so that in areas vulnerable to sea level hazards, redevelopment will not increase non-conformance and that eventually, uses will convert to conforming through permitted redevelopment.
Setbacks	Set building restrictions that limit the portions of a lot that can be used for development. When used for hazard concerns, they are normally defined by a measurable distance from an identifiable location such as a bluff edge, line of vegetation, dune crest, or roadway.	LCPs can establish the general guidance (including the time period over which the setback should be effective) and criteria for establishing setbacks from bluffs and dunes that take into consideration changes in retreat due to sea-level rise. CPDs should require detailed, site-specific analyses to determine the size of the setback to take into account sea-level rise.
Siting and design	Determine where development can be located in order for it to be safe from hazards over the economic life of the development.	Incorporate sea-level rise into existing hazard analyses as part of the siting and design process.

3. Shoreline Management and Shore Protection

Shoreline management is a term used to describe actions to proactively preserve or manage a shoreline area. Measures include programs to nourish beaches, restore sediment supply, or maintain dunes. Shore protection includes measures that serve to reduce or eliminate upland damage from wave action or flooding during storms, and include natural measures such as living shorelines or placement of sand and hardened options such as seawalls or riprap. The shoreline management and shore protective measures include:

- Beach nourishment and replenishment
- Dredging management
- Dune management
- Hard Protection
- Living Shorelines
- Maintenance or restoration of natural sand supply
- Removal of shoreline protection structures
- Sediment management
- Soft protection
- Waiver of right to future shoreline protection

Table 18. Shoreline Management and Shore Protection Measures

Category	Description	Applicability to sea-level rise
Beach nourishment and replenishment	Placement of sand on beaches to reduce erosion, enhance recreation, or preserve or enhance the aesthetic and habitat value of beaches. Sand sources may include offshore dredge sites ("borrow areas"), nearby harbor or channel dredging projects, wetland restoration projects or inland development. Generally has fewer environmental drawbacks than hard armoring, but can negatively affect species living, feeding, and nesting on the beach, especially during and immediately after sand placement. Most effective for areas with some existing beach.	LCPs can identify locations where beach nourishment may be appropriate, possibly through a Regional Sediment Management program. If beach nourishment is appropriate, the LCP should establish criteria for the design, construction and management of the nourishment area that includes likely changes in beach conditions due to sea-level rise into beach nourishment and replenishment plans.
Dredging management	Dredging involves the removal of sediment from harbor areas to facilitate boat and ship traffic or from wetland areas for restoration.	Dredging management actions and plans may need to be updated to account for elevated water levels. LCPs and CDPs should facilitate delivery of clean sediment extracted from dredging to nearby beaches where needed.
Dune management	Establish management actions to maintain and restore dunes. Dunes provide buffers against erosion and flooding by trapping windblown sand, storing excess beach sand, and protecting inland areas, and they also provide habitat. Most effective for areas with some existing dune habitat and where there is sufficient space to expand a foredune beach for sand exchange between the more active (beach) and stable (dune) parts of the ecosystem.	LCPs can identify existing dune systems and develop or encourage the development of management plans to enhance and restore these areas, including consideration of ways that the system will change with rising sea level. CDPs for dune management plans may need to include periodic reviews so the permitted plans can be updated to address increased erosion from sea-level rise, and the need for increased sand retention and replenishment.

Hard Protection	"Hard" coastal protection is a broad term for most engineered features such as seawalls, revetments, cave fills, and bulkheads that block the landward retreat of the shoreline. Breakwaters, groins, and jetties may or may not be considered hard protection, depending upon their purpose and use with other "soft" protection.	LCPs can discourage the use of hard protection unless no other feasible alternative is available. LCPs should also develop design standards for the more frequently used hard protection and require designs that address or can be adapted to changing sea level. CDPs should require that hard protection be monitored for damage from sea-level rise hazards, that permits be re-opened after some time period to assess effectiveness in light of sea-level rise, and that removal options be incorporated into the design, in the event the structure may no longer be useful or appropriate in the future.
Living shorelines	Living shorelines are an approach to stabilize shoreline areas while maintaining valuable habitat and natural shoreline processes. These shorelines are designed with plants, sand, and limited amounts of rock to restore and enhance coastal habitats, promote sedimentation, and protect against shoreline erosion. They are effective in low-to-medium-energy coastal and estuarine areas and tidally influenced creeks, streams, and rivers.	LCPs can identify the local areas where living shorelines are most appropriate and develop guidance for implementation, monitoring, and evaluation. CDPs should require living shorelines where feasible and consistent with the Coastal Act. Require any living shorelines to take into account sea-level rise and storm events.
Maintenance or restoration of natural sand supply	Adjustment of the sediment supply has been one of the ways natural systems have accommodated changes from sea level. Maintenance or restoration of sediment involves identifying natural sediment supplies and removing and/or modifying existing structures or actions that impair natural sand supply, such as dams or sand mining.	LCPs should include policies and implementing standards that support nature-based responses to sea-level rise by maintaining and restoring natural sand supply. Where applicable, develop policies and standards to regulate sand mining, sand replenishment, and promote removal of dams or the by-passing of sand around dams. Plans should take into consideration changes in sand supply due to sea-level rise.

Removal of shoreline protection structures	When shoreline protection structures are no longer needed or are in a state of great disrepair, their removal can open beach or wetland areas to natural processes and provide for natural responses to sea-level rise.	LCPs can specify priority areas where shoreline protection structures should be removed, including areas where structures threaten the survival of wetlands and other habitat, or beaches, trails, and other recreational areas. Through the LCP, removal might be accomplished by offering incentives for removal to property owners and by incorporating removal of public structures into Capital Improvement Plans. Conditions can also be added to CDPs that require removal of shoreline protection structures after certain thresholds are passed.
Soft protection	"Soft" coastal protection methods replenish, enhance, or mimic natural buffers, and they include beach nourishment, living shorelines, or wetlands. Often most effective where similar soft protection already occurs. Many soft protection methods may also be part of a green infrastructure program.	LCPs can promote the use of soft protection where feasible, through requirements that it be considered whenever shoreline protection is deemed necessary, and through the development of an RSM program that can promote soft solutions. CDP applications should require detailed evaluation of soft options in the alternatives analysis and require the use of soft protection where feasible and consistent with the Coastal Act. Sea-level rise and storms should be incorporated into the siting and design of any soft protection projects.
Waiver of right to shoreline protection	Property owners waive the right to future shoreline protective devices. The waiver specifies that no bluff or shoreline protective device is allowed to protect the development if it is threatened by natural hazards in the future. Instead, development will be removed or relocated if threatened by natural hazards.	As part of a CDP, require property owners to waive their right to future shoreline protection devices. The LCP can contain a policy stating that CDPs should include the waiver as a condition to approval of new development.

4. Coastal Habitats

The coastal habitats category includes measures designed to protect and enhance coastal habitats, including wetlands, ESHA, and other habitats. Some coastal habitat measures include:

- Use of ecological buffer zones
- Incorporation of sea-level rise in restoration, creation, or enhancement of coastal habitats
- Facilitation of wetland migration
- Increased habitat connectivity
- Open space preservation and conservation
- Protection of ecologically critical areas and species
- Protection of refugia

Table 19. Measures for Natural Resources

Category	Description	Applicability to sea-level rise
Ecological buffer zones	Buffer zones are intended to protect sensitive habitats from the adverse impacts of development and human disturbance. An important aspect of buffers is that they are distinct ecologically from the habitat they are designed to protect.	LCPs can establish requirements for ecological buffers and provide guidance on how to establish or adjust these buffers to accommodate sea-level rise. CDPs should require buffers to be designed, where applicable, to provide "habitat migration corridors" that allow sensitive habitats and species to migrate inland or upland as sea level rises. To accommodate sea-level rise, the amount of buffer required between development and coastal habitats may need to be increased. The size of the buffer needed to allow for migration will vary depending on the individual wetland or habitat type, as well as site specific features such as topography and existing development.
Incorporation of sea-level rise in habitat restoration, creation, and enhancement	Restoration involves returning a degraded ecosystem or former ecosystem to a pre-existing condition or as close to that condition as possible. Creation involves converting one land-use type into another, such as converting dry land into a wetland. Enhancement includes increasing one or more of the functions performed by an existing ecosystem beyond what currently or previously existed.	Habitat restoration, creation, or enhancement projects should be designed to withstand impacts of sea-level rise and adapt to future conditions. As applicable, the LCP should contain policies to ensure restoration and management techniques account for future changes in conditions. CDPs for restoration projects should incorporate sea-level rise and provisions to ensure habitats can adapt with changing future conditions.

Facilitation of wetland migration	Reserve space for a "habitat migration corridor," or areas into which wetlands could migrate as sea-level rise induced inundation of existing wetland areas occurs.	In the LCP, identify potential habitat migration corridors. These areas could be reserved for this purpose in an LCP through land acquisition, use designations, zoning buffers, setbacks, conservation easement requirements, and clustering development. LCPs should also consider developing a plan for acquisition of important habitat migration corridors.
Increased habitat connectivity	Connectivity refers to the degree to which the landscape facilitates animal movement and other ecological flows. Roads, highways, median barriers, fences, walls, culverts, and other structures can inhibit movement of animals.	Develop LCP policies that will enable identification of important animal movement corridors. Develop regulations to protect these corridors for present and future conditions, taking into account habitat shifts from climate change. In LCPs and through CDPs, require that new structures such as highways, medians, bridges, culverts, and other development are designed to facilitate movement of animals.
Open space preservation and conservation	This measure involves preservation of land for its ecological or recreational value. It includes prohibiting development and any uses that conflict with ecological preservation goals.	LCPs can develop open space management plans that evaluate and consider the impacts of sea-level rise, extreme events, and other climate change impacts. LCPs and CDPs can dedicate open space and conservation areas through zoning, redevelopment restrictions, acquisition, easements, setbacks, and buffers.
Protection of ecologically critical areas and refugia	Protect ecologically critical areas, or areas that are important for the continued survival of a species or ecosystem (e.g. nursery grounds, spawning areas, or highly diverse areas) that could be adversely affected by sea-level rise. Also, protect refugia, or areas that may be relatively unaltered by global climate change and thus can serve as a refuge for coastal species displaced from their native habitat due to sea-level rise or other climate change impacts.	LCP land use designations and zoning, and standards for buffers, setbacks, and conservation areas can identify and protect refugia and ecologically-critical areas. Such areas can also be preserved through LCP land use designations and zoning, and standards for buffers, setbacks, conservation easements, and clustering development.

5. Water Quality/ Water Supply Management

Water quality and water supply management measures include actions to minimize adverse impacts to water quality due to sea-level rise, and to prepare for reduced availability of freshwater due to saltwater intrusion. Water quality and water supply management measures include:

- Elimination or reduction of ocean outfall
- Green stormwater infrastructure
- Ground water management
- Limited groundwater extraction from shallow aquifers
- Stormwater management

Table 20. Measures for Water Quality/ Water Supply Management

Category	Description	Applicability to sea-level rise
Elimination or reduction of ocean outfalls	An ocean outfall is a pipeline or tunnel that discharges municipal or industrial wastewater, stormwater, combined sewer overflows, cooling water, or brine effluents from desalination plants to the sea.	LCPs should identify areas where sea-level rise could affect flow of wastewater from outfalls and lead to backup and inland flooding. The LCP can include policies to require modifications to the outfall lines, the use of green infrastructure and redesign of waste and stormwater systems. CDPs for ocean outfalls should consider sea-level rise in design.
Green stormwater infrastructure	Employ natural, on-site drainage strategies to minimize the amount of stormwater that flows into pipes or conveyance systems. These strategies include green roofs, permeable pavements, bioretention (i.e. vegetated swales, rain gardens) and cisterns.	LCPs can include policies that require green infrastructure be used whenever possible in lieu of hard structures. Incorporate sea-level rise and extreme storms into the design.
Ground water management	Plan and coordinate monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of fostering long-term sustainability of the resource.	The LCP can add policies that specify limits on the use of groundwater. These policies should be made in accordance with other regional water planning efforts, such as Integrated Regional Water Plans. CDPs involving the use of ground water should develop a ground water management plan.

Limited groundwater extraction from shallow aquifers	Groundwater extraction from shallow aquifers can increase susceptibility to saltwater intrusion. Limiting or preventing extraction from vulnerable aquifers can reduce the impacts of saltwater intrusion and preserve fresh groundwater supplies.	LCPs or CDPs can add restrictions to the use of aquifers susceptible to saltwater intrusion and can encourage measures to recharge shallow aquifers that are depleted.
Stormwater management	Control the amount of pollutants, sediments, and nutrients entering water bodies through precipitation-generated runoff.	LCPs should include sea-level rise and extreme storms in stormwater management plans and actions. LCPs and CDPs for stormwater infrastructure should consider sea-level rise. Actions to reduce impacts from higher water levels could include widening drainage ditches, improving carrying and storing capacity of tidally-influenced streams, installing larger pipes and culverts, adding pumps, converting culverts to bridges, creating retention and detention basins, and developing contingency plans for extreme events.

6. Additional Actions

Additional actions include measures that the Coastal Commission recommends local governments or applicants consider to minimize risks from sea-level rise but that fall outside of the regulatory authority of the Coastal Act.

- Acquisition and buyout programs
- Modeling and mapping
- Monitoring
- Outreach and education
- Research and data collection

Table 21. Additional Actions

Category	Description	Applicability to sea-level rise
Acquisition and buyout programs	Acquisition includes the acquiring of land from the individual landowner(s). Structures are typically demolished or relocated, the property is restored, and future development on the land is restricted. Undeveloped lands are conserved as open space or public parks.	LCPs can include policies to encourage the local government to establish an acquisition plan or buyout program to acquire property at risk from flooding or other hazards.

Modeling and mapping	Modeling and mapping are tools for assessing climate change impacts and vulnerabilities within a planning area and illustrating potential outcomes of adaptation actions. Modeling enables analysis of potential impacts to an area under various sea-level rise scenarios. Maps portray how sea-level rise scenarios may intersect with coastal and marine resources, community assets and existing social and environmental vulnerabilities.	LCPs should rely upon the best available science in developing sea level guidance. Toward that end, models and mapping tools can be important for determining sea level hazards, and vulnerabilities and can help evaluate the utility of various adaptation strategies. Examples include the NOAA SLR Viewer, Our Coast Our Future, CoSMoS, and the Sea-Level Affecting Marshes Model.
Monitoring	Collect observations or data over time to track changes in the function or condition of a system.	Where appropriate, LCPs can establish regional monitoring programs to track changes in sea level, shoreline or ecosystem status, and the efficacy of adaptation measures. CDPs can require SLR monitoring programs as a condition of approval for more site-specific concerns. Key indicators may include flooding frequency, erosion rate, wave height, tidal range, vertical land movement, sedimentation rate, water quality, etc.
Outreach and education	Outreach includes provision of information to all stakeholders, and occurs at regular intervals throughout the planning and implementation process. It helps to gain support for planning and action implementation. Education involves systematic instruction, through formal systems such as schools or universities. It is important to include all relevant stakeholders in these processes.	For many people, sea-level rise is a new issue. Information on sea-level rise science and potential consequences may be useful in order for stakeholders to take an active role in updating the LCP for sea-level rise issues, or in the vulnerability and risk assessment efforts.
Research and data collection	Create a research agenda to address key data gaps and better utilize existing information.	Pursue new research to better understand the factors controlling sea-level rise, baseline shoreline conditions, ecosystem responses to sea-level rise, potential impacts and vulnerabilities, and the efficacy of adaptation tools.